

Row orientation effects on FR/R light ratio, growth and development of field-grown bush bean

Karan Kaul and M. J. Kasperbauer

Kaul, K. and Kasperbauer, M. J. 1988. Row orientation effects on FR/R light ratio, growth and development of field-grown bush bean. – *Physiol. Plant.* 74: 415–417.

Bush bean (*Phaseolus vulgaris* L. cv. Tenderette) plants were grown in north-south (N-S) and east-west (E-W) rows under field conditions to test effects of row orientation on reflected far-red (FR) light patterns and on shoot size and edible bean productivity. Soil water and nutrients were adequate. Plants in N-S rows received slightly higher ratios of FR relative to red (R) light, because of heliotropic movement of the leaves. Plants in N-S rows partitioned more dry matter to shoots and edible green beans than those in E-W rows. We conclude that row orientation of broadleaf plants can affect the FR/R light ratio and the phytochrome-mediated regulation of plant development under field conditions.

Key words – Beans, far-red/red ratio, heliotropic movement, *Phaseolus vulgaris*, phytochrome.

K. Kaul (corresponding author), CRS Plant and Soil Science Research, Kentucky State Univ., Frankfort, KY 40601, USA; M. J. Kasperbauer, Coastal Plains Research Center, Agricultural Research Service, US Dept of Agriculture, Florence, SC 29502-3039, USA.

Introduction

Recent studies with field-grown soybean [*Glycine max* (L.) Merr.] have shown that row orientation can affect plant growth and seed yield on the light-colored, sandy soils of the coastal plains of southeastern USA (Hunt et al. 1985). Yield from N-S oriented rows was usually higher than that from E-W oriented rows when plants received adequate water and nutrients. Kasperbauer (1987) theorized that the differences in yields observed by Hunt et al. (1985) may have been related to differences in spectral distribution of light received by plants in N-S vs those in E-W rows, and that the difference in spectral distribution of light associated with row orientation may be influenced by solar angle as well as by heliotropic movement of the leaves. Experiments with field-grown soybean showed that plants in N-S rows received a slightly higher FR/R ratio near the end of

each day and they partitioned more photosynthate to shoots but less to roots relative to plants in E-W rows. The effects of FR/R ratio on plant growth and yield observed in the field could be duplicated by regulating the FR/R ratio under a controlled environment, which demonstrated involvement of phytochrome in the regulation of photosynthate partitioning within the plants (Kasperbauer 1987).

Based on the above studies with soybean on sandy soils of the coastal plains, it was hypothesized that other broadleaf plants in N-S rows should also: (a) receive slightly higher FR/R ratio, (b) produce larger shoots and (c) have higher yields in other geographic areas. The present study was undertaken to assess the effects of row orientation on canopy light, shoot growth and edible green bean yield from bush beans (*Phaseolus vulgaris* L.) grown on darker-colored soils in Kentucky, USA.

Received 7 April, 1988; revised 13 June, 1988

Abbreviations – E-W, east-west; FR, far-red light; N-S, north-south; PAR, photosynthetically active radiation; R, red light.

Materials and methods

Plant material

Bush bean (*Phaseolus vulgaris* L. cv. Tenderette) plants were grown in field plots on the Kentucky State Univ. research farm near Frankfort (KY, USA) in 1987. Each plot consisted of six 12-m rows 1 m apart. The row orientation was either N-S or E-W. There were two planting dates (22 July and 3 August) for each row orientation. Plots were overseeded and then thinned to 10 plants m⁻¹ of row. Data on edible green bean yield and shoot weight were collected from the central 8 m of each of the 4 middle rows of each plot. Edible green beans were harvested twice from the first planting (10 and 11 weeks after planting) and once from the second planting (9 weeks after planting). Bean yields are presented as fresh weight. A killing frost occurred two days after the last bean harvest. Shoots were sampled the next day by cutting them at the soil surface. Shoot dry weights were determined after oven drying at 60°C for 48 h.

Light measurement

Photosynthetically active radiation (400–700 nm) and spectral distribution of light received by leaves near the top of the canopies were measured in N-S and E-W rows of both planting dates. The first and second plantings were 8 and 6 weeks old, respectively, when light measurements were taken. Light measurements were taken on a cloudless day with a LiCor Spectroradiometer LI-1800 equipped with a remote light collector on a 1.5 m fiber optic probe. The light collector was 1.5 × 1.5 × 3.5 cm and had a 0.6 cm (diam.) window. Spectral irradiances at 735 and 645 nm were used to calculate the FR/R ratios, because these are the FR and R action peaks, respectively, in green plants (Kasperbauer et al. 1963, 1964). All light measurements were taken on a sunny day at 11 00, 13 30, and 15 30 h.

For photosynthetically active radiation (PAR) and FR/R measurements, a single plant was removed from each row orientation and planting date, and replaced with a wooden stake to support the remote light collector. The top of each stake was the height of the shoot apex of adjacent plants. The light collector was placed on top of the stake and oriented to measure incoming light parallel to the soil surface. Incoming light was measured from north, south, east and west. Measurements for all 3 times were taken in the same sequence. For each row orientation, plant age and time of day, FR values from all 4 directions were added, as were R values. The FR/R ratios were calculated. Means and SE were determined for each row orientation.

Light spectral measurements were taken near the top

of the canopy, because the classical experiments of Borthwick and Parker (1940) demonstrated that the most recent fully-expanded leaf was most effective for study of photomorphogenic responses. Soybean plants trimmed to the most recent fully-expanded leaf were used on the Beltsville Spectrograph to develop the action spectra (Parker et al. 1946), which contributed greatly to the discovery of phytochrome. Also, recent research clearly shows that the FR/R ratio received near the shoot apex influences development of the shoot (Kasperbauer, 1987).

Results and Discussion

Canopy light

Both PAR and the FR/R ratio of light received in plant canopies were determined in N-S vs E-W rows (Tab. 1). Mean values for photosynthetic light did not differ with row orientation. However, the FR/R ratio (photomorphogenic light) was higher for N-S than for E-W rows. The row orientation effects on FR/R ratio were similar to those found previously for soybean (Kasperbauer et al. 1984). The earlier research with soybean showed that the FR/R ratio acted through the phytochrome system within the plant to regulate photosynthate partitioning among shoots and roots. A higher FR/R ratio resulted in greater partitioning of photosynthate to shoots, and a higher shoot/root ratio for soybean plants grown under a controlled environment. The spectral distribution of light received by E-W vs N-S oriented rows was different (Tab. 1). The difference appears to be related to the effects of heliotropic movement of leaves on the pattern of reflected FR as hypothesized by Kasperbauer (1987).

Plant responses

The amount of dry matter partitioned to shoots was higher in plants grown in N-S rows than those grown in E-W rows (Tab. 2). Yields of edible green beans were also higher in N-S rows (Tab. 2). That is, plants in N-S

Tab. 1. Photosynthetic and photomorphogenic light received at the shoot apex of bush bean plants growing in north-south (N-S) vs east-west (E-W) rows. Incoming light was measured from the north, south, east and west at 11 00, 13 30 and 15 30 h on a cloudless day near Frankfort, KY, USA. Each value in the table is the mean ± SE for 2 planting dates and 3 times during the day.

Light	Row orientation	
	N-S	E-W
Photosynthetic (400–700 nm) ($\mu\text{mol m}^{-2} \text{s}^{-1}$)	389±62	393±59
Photomorphogenic (FR/R photon ratio)	1.85±0.23	1.48±0.13

Tab. 2. Effects of row orientation on shoot growth and edible green bean yield in field-grown bush beans. Shoot dry weight was determined after oven drying at 60°C for 48 h. Bean weight was determined by weighing fresh, whole green beans. Bean weight data for first planting represent two pickings, while those for second planting represent only one picking. Each value is the mean per plant \pm SE.

Group	g DW shoot (plant) ⁻¹		g FW green beans (plant) ⁻¹	
	N-S	E-W	N-S	E-W
First planting	14.2 \pm 2.4	10.0 \pm 2.2	59.0 \pm 8.3	43.0 \pm 4.1
Second planting	11.0 \pm 2.1	7.3 \pm 0.7	24.0 \pm 4.4	14.3 \pm 3.1

rows, which received slightly higher FR/R ratios, partitioned more dry matter to shoots and to developing fruits.

Results of the present experiment with bush bean on Kentucky soil are consistent with those hypothesized on the basis of a recent report on soybean responses to row orientation on sandy soils of South Carolina (Kasperbauer 1987). It is apparent from the present study (Tabs 1 and 2) and earlier research (Kasperbauer et al. 1963, 1964) that very subtle differences in FR/R ratio can act through the phytochrome system within growing plants and regulate partitioning of photosynthate within the plant. Consequently, management practices as subtle as row orientation, and physiological phenomena such as heliotropic movement of leaves can modify the FR/R ratio in light received by growing bean and other broad-leaf plants enough to modify plant productivity.

It is important to note that basic concepts involving the pattern of reflected FR light, which were developed with soybean on light-colored sandy soils of the South Carolina coastal plain, are applicable to bush bean on dark-colored silt loam soil of Kentucky, which also has very different weather patterns. We hypothesize that bean and other broadleaf plants would exhibit responsiveness to row orientation over a wide range of geographic areas. Knowledge of row orientation effects on FR/R ratio and its action via the phytochrome system might lead to crop-soil-water-light management systems that improve crop productivity with little or no additional cost to the home gardener or commercial grower.

Acknowledgements – We thank Mr J. Lamb, Mr W. Sanders, Mr M. Stone and Ms L. Winkle for technical assistance. Administrative support of Dr H. R. Benson and Dr P. G. Hunt is gratefully acknowledged. Mention of a trade name does not constitute a guarantee or warranty of the product by USDA/CSRS and USDA/ARS and does not imply approval to the exclusion of other products that may also be suitable.

References

- Borthwick, H. A. & Parker, M. W. 1940. Floral initiation in Biloxi soybeans as influenced by age and position of leaf receiving photoperiodic treatment. – *Bot. Gaz.* 101: 806–817.
- Hunt, P. G., Sojka, R. E., Matheny, T. A. & Woolum, A. G. II. 1985. Soybean response to *Rhizobium japonicum* strain, row orientation, and irrigation. – *Agron. J.* 77: 720–725.
- Kasperbauer, M. J. 1987. Far-red light reflection from green leaves and effects on phytochrome-mediated assimilate partitioning under field conditions. – *Plant Physiol.* 85: 350–354.
- , Borthwick, H. A. & Hendricks, S. B. 1963. Inhibition of flowering of *Chenopodium rubrum* by prolonged far-red radiation. – *Bot. Gaz.* 124: 444–451.
- , Borthwick, H. A. & Hendricks, S. B. 1964. Reversion of phytochrome 730 (P_r) to P660 (P_f) in *Chenopodium rubrum* L. – *Bot. Gaz.* 125: 75–80.
- , Hunt, P. G. & Sojka, R. E. 1984. Photosynthate partitioning and nodule formation in soybean plants that received red or far-red light at the end of the photosynthetic period. – *Physiol. Plant.* 61: 549–554.
- Parker, M. W., Hendricks, S. B., Borthwick, H. A. & Scully, N. J. 1946. Action spectrum for the photoperiodic control of floral initiation of short-day plants. – *Bot. Gaz.* 108: 1–26.